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Workshop 8

Pipeline Issues

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Abstract

The declining pool of graduates, the lack of rigorous preparation in science and mathematics, and the declining interest in science and engineering careers at the precollege level promises a shortage of technically educated personnel at the college level for industry, government, and the universities in the next several decades. The educational process, which starts out with a large number of students at the elementary level, but with an ever smaller number preparing for science and engineering at each more advanced educational level, is in a state of crisis. These pipeline issues, so called because the educational process is likened to a series of ever smaller constrictions in a pipe, were examined in a workshop at the Space Grant Conference and a summary of the presentations and the results of the discussion and the conclusions of the workshop participants is reported.

Introduction

A major concern in the fields of aerospace science and engineering is the lack of sufficient numbers of students choosing study and work in these professions. In the next two decades this problem will be compounded by a decline in the number of high school graduates, the poor preparation of many of these graduates, especially in science and mathematics, and the declining interest among them in science and engineering careers. These problems are a part of the so called pipeline effect wherein the educational process, which starts out with a large number of students at the elementary level, but with an ever smaller number preparing for science and engineering at each more advanced educational level, is likened to a series of ever small constrictions in a pipe. Efforts to date to offset the effects of the declining numbers from traditional sources, that is from among white males, by tapping less traditional sources, namely women and minorities, have been less than successful.

The Pool of College Age Students

Data presented in the Interim Report of the Task Force on Women, Minorities, and the Handicapped in Science and Technology, September, 1988, entitled "Changing America: The New Face of Science and Engineering", outline the problem and its causes. To quote from the report:

The percentage of young Americans preparing for careers in science and engineering has been declining steadily. Our most experienced scientists and engineers, recruited after Sputnik, will be retiring in the 1990s. Meanwhile, by the year 2000 the number of jobs requiring college degrees will increase dramatically. The educational pipeline from prekindergarten through the Ph.D. is failing to produce the scientifically literate and mathematically capable workers needed to meet future demand.

In a series of charts and figures the evidence is set forth.

1. Between 1980 and 2000 the number of 18-24 years old in the U.S. population will decline by 19 percent while the overall population increases by 18 percent.
2. Of the new workers entering the labor force by the year 2000, only 15 percent will be white men (the traditional source of scientific and engineering manpower), and of the rest will be white women, members of minority groups, and immigrants (the groups traditionally most likely not to enter science and engineering fields).
3. The scores of American twelfth grade students in mathematics and science achievement tests is among the lowest among industrialized countries.
4. Interest among freshmen in science and engineering is down dramatically (one quarter to one third or more depending on the field) in the last decade.
5. Decline in interest in engineering and science of Americans carries through to graduate school where participation of foreign nations has increased dramatically.
6. A shortfall of science and engineering graduates needed to serve industry may reach several hundred thousand by 2010.

In another report, prepared by the Western Interstate Commission for Higher Education, The College Board, and Teachers Insurance and Annuity Association, entitled "High School Graduates: Projections by States, 1986 to 2004", the problem of the projected student supply is reported by region and by state. This report shows that

1. Between 1988 and 1994 there will be a 12 percent drop in the number of high school graduates nationwide; by 2004 there will be 6 percent increase over 1988.

2. There will be dramatic differences between regions with the West and South/South Central showing increases and the Northeast and North Central showing declines between 1988 and 2004.
3. There will be dramatic differences between states within regions. A few states will show large gains but many will show declines.

Preparation for College

Much more worrisome than the size of the total pool of high school graduates is the lack of preparation in basic subjects. Many very bright potential students for science and engineering are woefully unprepared to go on to college in these fields. Many have not taken appropriate science and mathematics courses in high school, others have taken them but not learned them well, while others have taken them and not found them interesting.

Many social, cultural and economic factors have led to a decline in the quality and quantity of K-12 education, especially in science, mathematics, and written and oral expression. This decline is most evident in inner cities with large minority enrollments, but is increasingly evident throughout primary and secondary education. Some of those factors are:

1. Poor teaching. Low teacher expectations.
2. Poor facilities and learning environment.
3. Short school days, short school year, no homework.
4. Lack of discipline. Drugs.
5. Poor work ethic; low self esteem; absenteeism; negative peer pressure.
6. Lack of parental and community support.

Until there is substantial reform in secondary education, the pool of prepared students will remain very low.

Declining Interest in Science and Engineering

Of equal concern is the lack of interest by potential students for careers in science and engineering. There are many reasons.

1. Social, cultural, and economic factors that keep many students away from science and engineering careers.
 - a. Perception of science, mathematics, and engineering are too difficult for most students.
 - b. Perception of science, mathematics, and engineering are dull subjects.
 - c. Higher work loads and longer degree programs compared to liberal arts.
 - d. Perception of science, mathematics, and engineering as not people oriented - in contrast to careers in law, medicine, social work, etc.
 - e. Perception of negative impact of science and technology on environment.
 - f. Close association of science, mathematics, and engineering with war related activities.
 - g. Perception of low pay compared to law, medicine, entertainment, etc. Growing opportunities in the service sector of the economy.
 - h. High cost of higher education.
2. Additional social, cultural, economic factors that keep women away from science and engineering careers.
 - a. Widespread belief that science and engineering are not for girls. Competing careers that are traditionally female - nursing, teaching, library science, etc.-and, therefore, safe for a girl to pursue.
 - b. Tracking of girls out of physics, higher mathematics, etc.; belief that girls can not do as well as boys in these subjects.
 - c. No role models; belief that women are not accepted in industrial employment (except as secretaries).
 - d. Marriage and child raising alternative.
3. Additional social, cultural, and economic factors that keep minorities away from science and engineering careers.
 - a. No role models; perception of past discrimination in industry.

- b. Tracking of minority students out of physics, higher mathematics, etc., because they are thought less likely to go to college - a self fulfilling prophecy.
- c. Likely first generation to go to college; therefore less academic and career guidance and counseling from home.
- d. Misleading concepts of alternatives: sports, entertainment, etc.
- e. Low family financial support expectations.
- f. More likely to be in one of the weaker high schools with poorer preparation.

The Lack of Attraction of Graduate Education

Among those who do complete undergraduate education in science and engineering, many do not find graduate education to be sufficiently attractive. Among the reasons are:

- 1. Attractive job offers. Most firms deliberately try to hire at the BS level those students who have the most potential for graduate study.
- 2. Low pay differential for higher degrees.
- 3. Perception that turning to management, which does not require higher technical degrees, is the only way to ensure promotion. Many turn to advanced degrees in business, law, etc.
- 4. High cost of graduate education. Limited financial aid (when compared to job offers and earning potential). Debt from undergraduate years.
- 5. Academic burn out from high undergraduate work loads.

What Can Be Done

To stimulate some discussion, here are some suggestions in broad general categories of what might be done.

- 1. Push for reform in primary and secondary education.
- 2. Inform potential college students of the opportunities and rewards that abound in science and engineering careers.

3. Breakdown stereotypical views of science and engineering.
4. Breakdown stereotypical views of the opportunities for women and minorities.
5. Make science and engineering undergraduate more attractive.
6. More clearly articulate the need for graduate education.
7. Make science and engineering careers more attractive.

Discussion

The initial discussion was concerned with the end of the pipeline, the graduate program, and the issue of foreign versus US graduate students. It was agreed that foreign students are valuable and welcome addition to our graduate schools but there was belief that a more generous supply of US students would be desirable. We should not depend so heavily on importing students and, for that matter, importing employees at the post graduate degree level. The discussion then shifted down to the undergraduate level. The need to counsel, encourage, support, etc., more of the better undergraduate students to continue in graduate school was emphasized.

Will there be enough educated scientists and engineers in the next two decades? No one challenged the need for more scientists and engineers but the need for those educated in aerospace disciplines will depend on world events and national policy. The large number of retirements coming in the next decade in the aerospace industries was mentioned as a factor.

At this point in the discussion the issue of quality versus quantity was introduced. Within the room there seemed to be more concern about quality than quantity. It was noted that at the last downturn in quantity - late 60's and early 70's - the downturn in quantity was accompanied by a sharp drop in quality. The belief was widely shared that efforts to prevent a quality loss this time around should be given priority, and, perhaps, the quantity problem was not as serious as some believe.

At the secondary school level, the lack of counseling or other means to let students know what engineering and science careers are all about, was expressed as a major concern. The discussion shifted quickly, however, to the middle school level where this is most painfully apparent. The need for good guidance at that level was considered essential because this is where the students are making the decisions that will keep them available or rule them out of science and engineering careers. It was noted that girls and minority students have still tracked out courses of study essential for college preparation whether by choice or poor advice.

At the primary school level the teacher interested or enthusiastic about science was considered desirable. The quest for quality starts here. And without the quality throughout primary and secondary education we are limited in what we can do about the quantity of future scientists and engineers.

Conclusions

In the last few minutes of discussion there was substantial agreement on the following conclusions:

1. There is a need for more scientists and engineers, but since we cannot do much about the birth rate of the 1970's and 80's, we shall have to act so that those high school graduates who are potential candidates are well prepared and interested in pursuing such careers.
2. Our best opportunity at the primary school level is to work with teachers. These teachers must have a better understanding and appreciation of science and mathematics as it relates to future the development of the students. They must make the student both more proficient and more interested in these subjects.
3. The middle school students are most critical. We must develop programs which help improve instruction, which help students make proper choices of courses, and which ensure that they learn these subjects. We must not only work with teachers but we must intervene directly with the students to provide role models, counseling, and encouragement.
4. We must develop programs at the high school level to reinforce and continue the efforts made at the middle school level.

5. Undergraduate college students must be encouraged to continue in graduate school in greater numbers. We can continue to pursue, but not depend so strongly on, imported graduate students.
6. We are concerned with the quantity of students in science and engineering but are even more concerned about quality. Those efforts made to increase the number of students in science and engineering should also have the purpose of improving the quality of the students, the quality of their preparation, and the quality of programs they enter.